Nanoscale Science and Technology Division
Room B113 - Session NS2+2D+EM-TuA

Light-Matter Interactions at the Nanoscale

Moderator: Nancy Burnham, Worcester Polytechnic Institute

4:40pm **NS2+2D+EM-TuA-8 Highly Tunable Room-Temperature Exciton-Polariton Strong Coupling from Monolayer WSe_2 in Nanocavities***, P. Schuck, **Thomas Darlington**,* Columbia University **INVITED**

In the interaction of light and matter, strong coupling occurs when exchange between a photon and electronic transitions exceeds the relative loss rate leading to hybridization of the optical and electronic states. The behavior is well known in cavity quantum electrodynamics (QED), and is a fundamental ingredient in single photon quantum logic gates. In solid-state systems, many strong coupling phenomena have been explored between different material excitations. Plasmons in particular have attracted great interest owing to their small mode volumes, allowing for strong coupling of a plasmon and single quasi-particles excitations such as excitons, potentially recreating in the solid-state, at the nanoscale, and at elevated temperatures many of the phenomena previously studied in traditional trapped atom QED.

Here, I describe our investigations of strong coupling between TMD excitons and a tunable plasmonic nanocavity formed between a plasmonic tip and gold substrate. Strong coupling between plasmons and excitons has been observed in excitons systems: e.g., J-aggregates, and colloidal quantum-dots. While these systems offer large coupling strengths, the exciton transition energies are largely fixed, and vary randomly depending on variations in growth conditions. By contrast, TMDs offer strong exciton emission and large tunability of exciton energy by applied strain. We utilized this tunability to control coupling strengths in nanocavities in a proof-of-principle nano-electro-mechanical system (NEMS) platform, demonstrating the ability to continuously tune, between weak and strong coupling conditions where we observe both upper and lower polariton bands.

5:20pm **NS2+2D+EM-TuA-10 Surface Plasmon Characterization in Ag Nanotriangles for Evaluation of Fano Resonance Conditions***, **Nabila Islam**,* Department of Physics, Portland State University*; R. Word,* Department of Physics, Portland State University, Portland, Oregon*; E. Abdul, S. Rananavare,* Department of Chemistry, Portland State University*; R. Könenkamp,* Department of Physics, Portland State University

Surface plasmon resonances in metal nanostructures allow confinement of the electromagnetic field well below the light diffraction limit and have attracted research interest for a broad range of sensing applications [1]. The comparably broad spectral width of surface plasmon based sensors can be improved by coupling the plasmon resonance to other resonances to generate Fano resonances with the distinctive and sharp asymmetric Fano line-shape. We used photoemission electron microscopy to explore the spectral and spatial behavior of plasmon resonances in structures consisting of a single nanoscale triangular platelet on a substrate providing coupling to a waveguide layer or to an optically active excitonic layer. In our experiments stationary and propagating surface plasmons are optically excited in the nano-triangle at wavelengths around 820-900nm, and multi-photon electron-emission is used to obtain images of the lateral surface plasmon distribution. An aberration-corrected photoemission microscope allowed us to obtain a spatial resolution of ~15nm and a femtosecond pulsed Ti-sapphire laser provided the photon intensities needed for the 3-photon photoemission imaging process [2]. The analysis of the obtained images is done in optical simulations of the same experimental set-up and by calculating the plasmon electric field distribution which is then used to analyze and interpret the photoemission micrographs. The analysis allows to identify the prominent surface plasmon modes and to analyze their interaction to form stationary resonance patterns and propagating modes. Fano-resonances are established in the simulation by placing the triangles in the vicinity of an optical waveguide using an appropriate spacer layer [3]. The simulation then allows to optimize this type of arrangement and to determine locations where the Fano-resonance amplitudes are most pronounced. Simulations of this kind were also applied to the case of gold triangles on substrates provided with exciton and spacer layers. Our results indicate that both the high plasmon field strengths typical for single nanoparticle structures and the sharp spectral features available in Fano-resonances can be combined in these single nano-particle structures, thereby allowing improved resolution in sensor applications.

References

[1] Kumar, D., Kumar Sharma, G., & Kumar, M. (2023). Materials Today: Proceedings, 74, 259–262. https://doi.org/10.1016/j.matpr.2022.08.149

[2] Stenmark, T., & Könenkamp, R. (2019). Physical Review B, 99(20). https://doi.org/10.1103/physrevb.99.205428

[3] Hayashi, S., Nesterenko, D. V., & Sekkat, Z. (2015). Applied Physics Express, 8(2), 022201. doi:10.7567/apex.8.022201

5:40pm **NS2+2D+EM-TuA-11 Interconnected Plasmonic Nanogap Antennas for Photodetection via Hot Carrier Injection***, **John Grasso**, R. Raman, B. Willis,* University of Connecticut

Modern integrated circuits have active elements on the order of nanometers; however, optical devices are limited by diffraction effects with dimensions measured in wavelengths. Nanoscale photodetectors capable of converting light into electrical signals are necessary for the miniaturization of optoelectronic applications. Strong coupling of light and free electrons in plasmonic nanostructures efficiently confines light into sub-wavelength volumes with intense local electric fields. Localized electric fields are amplified in nanogap regions between nanostructures where enhancements can reach over 1000. Hot carriers generated within these high field regions from nonradiative decay of surface plasmons can be injected into the conduction band of semiconductors at room temperature, enabling sub-bandgap photodetection. The optical properties of these plasmonic photodetectors can be tuned by modifying antenna materials and geometric parameters like size, thickness, and shape. Electrical interconnects provide connectivity to convert light into electrical signals. In this paper, we will describe the optical properties of plasmonic nanostructures with electrical interconnects and compare experiment and theory using finite-difference time-domain (FDTD) simulations. We will present experimental extinction data and FDTD simulations to elucidate how geometric structure and dielectric properties influence optical properties. We will present sub bandgap photodetection for nanostructures integrated with ALD deposited TiO_2, and investigate both wavelength and polarization dependence. We will also discuss how plasmonic heating effects contribute to photocurrent generation. These plasmonic nanogap antennas are subwavelength, tunable photodetectors with sub-bandgap responsivity for a broad spectral range.

Author Index

Bold page numbers indicate presenter